

SEE Test Report V1.0
 Heavy ion SEE test of TPS76701 from TEXAS INSTRUMENTS
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I. Introduction

This study was undertaken to determine the single event destructive and transient susceptibility of the TPS76701 low dropout linear adjustable voltage regulator. The device was monitored for transient interruptions in the output signal and for destructive events induced by exposing it to a heavy ion beam at the Lawrence Berkeley Laboratory (LBL) Cyclotron Single Event Effects Test Facility. This test was performed in the frame of NEPP project.

II. Devices Tested

The sample size of the testing is three devices. Two devices were exposed and one served as a control sample. The test samples lot date code is unknown as there is no date code information in the package marking of the test samples.

The device technology is 1 μm BiCMOS (LBC3S). The device is packaged in a 20-pin TSSOP Power-PAD (PWP) package. The device was prepped for test by delidding.

III. Test Facility

Facility: LBL Cyclotron Single Event Effects Test Facility, (10 MeV/u cocktail)
Flux: 8×10^2 to 3×10^4 particles/cm²/s.
Fluence: all tests were run to at least 1×10^6 p/cm² or until a sufficient (>100) number of transient events occurred.

The ions and LET values planned for these tests are shown in Table 1.

Table 1: characteristics of ions used for the experiments
(10 MeV/u cocktail)

Ion	Energy (MeV)	LET (MeVcm ² /mg)	Range (μm)
¹⁸ O	184	2.22	227
⁴⁰ Ar	400	9.74	130
⁶⁵ Cu	659	21.33	110
⁸⁶ Kr	886	31.28	110
¹³⁶ Xe	1330	58.72	97

IV. Test Conditions

Test Temperature: Room Temperature
Bias conditions $V_{in} = 3.3V$
 $V_{out} = 1.5V$

Devices were biased as shown in Figure 1. Different test conditions are presented in Table 2. Remote loads used were resistive loads.

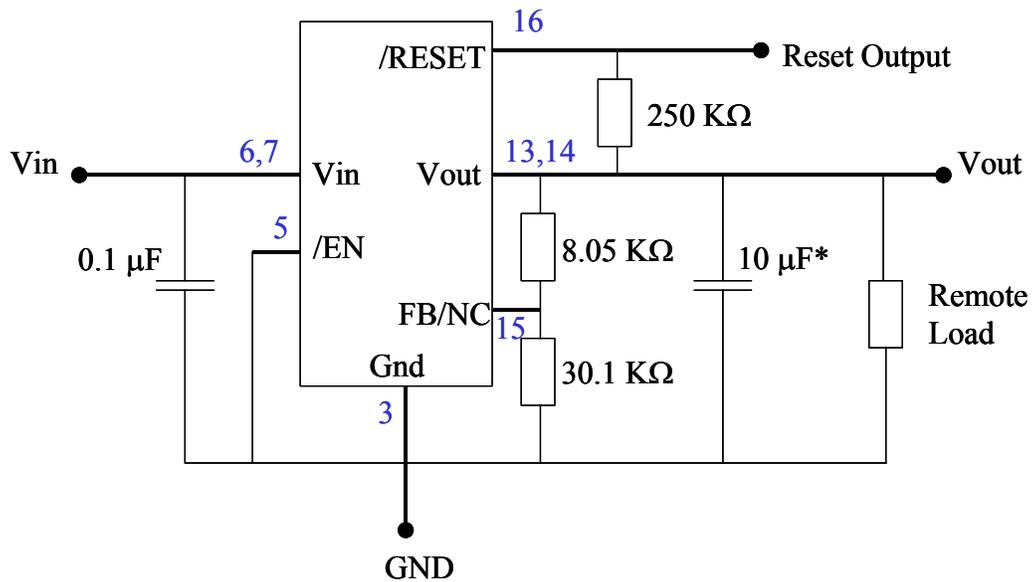


Figure 1: Bias conditions, *10 μF output capacitor ESR is between 50 m Ω and 1.5 Ω

Table 1: Test conditions

V_{in} (V)	V_{out} (V)	I_{out} (mA)
3.3	1.5	10
3.3	1.5	50
3.3	1.5	100
3.3	1.5	500
3.3	1.5	1000

V. Test Methods

Test circuit, as shown in Figure 2, for the adjustable regulator contains a power supply for the input voltage, a load for drawing current, and a digital scope for capturing any output anomalies. Once the programmable output is present and the load conditions are set, the digital scope is set to trigger on and voltages that are above or below a predetermined threshold (set to 75 mV).

Once the adjustable regulator receives the input voltage, it produces a regulated output. The digital scope triggered for both voltage dropouts and over voltage conditions at the output terminal.

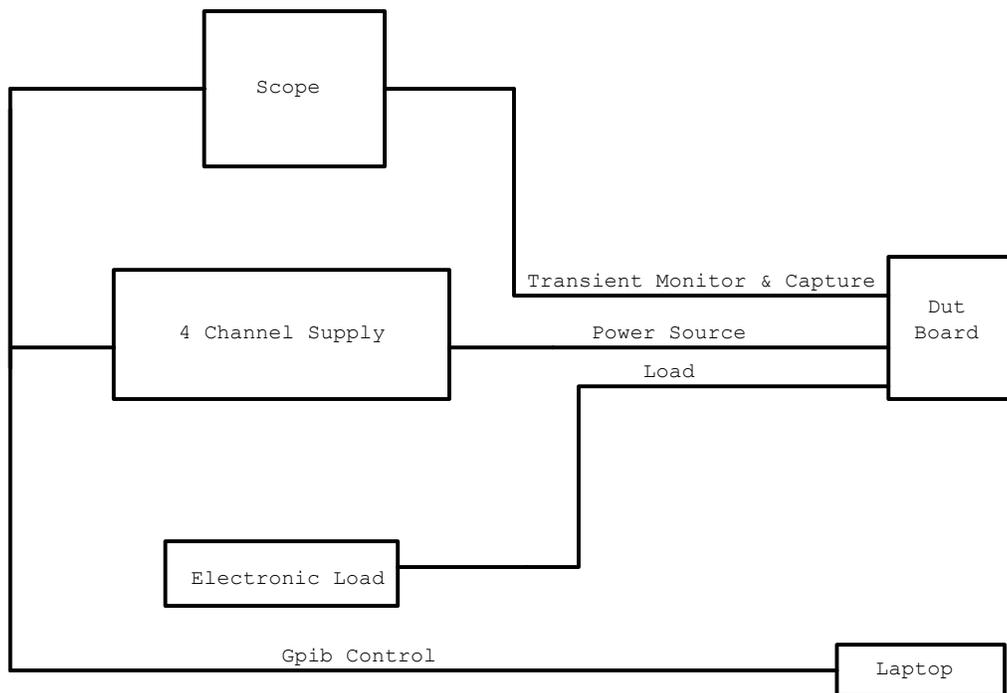


Figure 2. Overall Block Diagram for the testing of the TPS76701Q.

VI. Test results

Detailed test results are shown in Table 3. No destructive event was observed up to the maximum tested LET of 83 MeVcm²/mg. TPS76701 has a high sensitivity to SET. SET cross sections curves are shown in Figure 3. SET sensitivity does not vary significantly with output current. However, transient characteristics vary with output current. Transient amplitude and duration increase with output current. For the highest output current tested, 1 A, heavy ion can trigger device internal protection circuits.

Table 3: detailed test results

Run #	SN #	Vin (V)	Vout (V)	Iout (mA)	ION	LET (MeVcm ² /mg)	TILT (°)	Eff LET (MeVcm ² /mg)	Fluence (#/cm ²)	SET #	X SET (cm ² /dev)
2	1	3.3	1.5	10	Kr	31.28	0	31.28	4.92E+05	369	7.50E-04
3	1	3.3	1.5	10	Kr	31.28	0	31.28	1.47E+05	107	7.28E-04
4	1	3.3	1.5	1000	Kr	31.28	0	31.28	7.75E+04	102	1.32E-03
5	1	3.3	1.5	1000	Kr	31.28	0	31.28	8.97E+04	121	1.35E-03
6	1	3.3	1.5	1000	Kr	31.28	45	44.24	6.39E+04	109	1.71E-03
7	1	3.3	1.5	500	Kr	31.28	45	44.24	8.05E+04	103	1.28E-03
8	1	3.3	1.5	500	Kr	31.28	0	31.28	1.39E+05	111	7.99E-04
9	1	3.3	1.5	100	Kr	31.28	0	31.28	1.25E+05	100	8.00E-04
10	2	3.3	1.5	100	Kr	31.28	0	31.28	1.44E+05	107	7.43E-04
11	2	3.3	1.5	1000	Kr	31.28	0	31.28	8.41E+04	109	1.30E-03
12	2	3.3	1.5	1000	Kr	31.28	45	44.24	6.38E+04	108	1.69E-03
13	2	3.3	1.5	500	Kr	31.28	45	44.24	1.03E+05	102	9.90E-04
14	2	3.3	1.5	500	Kr	31.28	0	31.28	1.33E+05	100	7.52E-04
15	1	3.3	1.5	500	Kr	31.28	0	31.28	1.14E+05	103	9.04E-04
16	1	3.3	1.5	500	Ar	9.74	0	9.74	7.77E+05	99	1.27E-04
17	1	3.3	1.5	500	Ar	9.74	45	13.77	6.71E+05	104	1.55E-04
18	1	3.3	1.5	1000	Ar	9.74	45	13.77	5.01E+05	105	2.10E-04
19	1	3.3	1.5	1000	Ar	9.74	0	9.74	5.84E+05	115	1.97E-04
20	1	3.3	1.5	10	Ar	9.74	0	9.74	1.43E+06	100	6.99E-05
21	1	3.3	1.5	100	Ar	9.74	0	9.74	1.26E+06	104	8.25E-05
23	2	3.3	1.5	100	Ar	9.74	0	9.74	1.28E+06	110	8.59E-05
24	2	3.3	1.5	10	Ar	9.74	0	9.74	1.28E+06	105	8.20E-05
25	2	3.3	1.5	500	Ar	9.74	0	9.74	9.77E+05	109	1.12E-04
26	2	3.3	1.5	500	Ar	9.74	45	13.77	7.80E+05	116	1.49E-04
27	2	3.3	1.5	1000	Ar	9.74	45	13.77	6.87E+05	144	2.10E-04
28	2	3.3	1.5	1000	Ar	9.74	0	9.74	6.37E+05	131	2.06E-04
29	2	3.3	1.5	1000	Ne	3.45	0	3.45	1.41E+06	100	7.09E-05
30	2	3.3	1.5	500	Ne	3.45	0	3.45	3.22E+06	105	3.26E-05
31	2	3.3	1.5	100	Ne	3.45	0	3.45	3.67E+06	104	2.83E-05
32	2	3.3	1.5	10	Ne	3.45	0	3.45	2.92E+06	102	3.49E-05
33	1	3.3	1.5	10	Ne	3.45	0	3.45	3.28E+06	112	3.41E-05
34	1	3.3	1.5	10	Ne	3.45	45	4.88	2.27E+06	110	4.85E-05
35	1	3.3	1.5	100	Ne	3.45	45	4.88	2.05E+06	108	5.27E-05
36	1	3.3	1.5	100	Ne	3.45	0	3.45	3.01E+06	102	3.39E-05
37	1	3.3	1.5	500	Ne	3.45	0	3.45	2.79E+06	102	3.66E-05
38	1	3.3	1.5	500	Ne	3.45	45	4.88	1.77E+06	113	6.38E-05
39	1	3.3	1.5	1000	Ne	3.45	45	4.88	9.44E+05	109	1.15E-04
40	1	3.3	1.5	1000	Ne	3.45	0	3.45	1.75E+06	104	5.94E-05
41	1	3.3	1.5	10	Xe	58.72	0	58.72	2.25E+05	103	4.58E-04
42	1	3.3	1.5	10	Xe	58.72	45	83.04	2.03E+05	96	4.73E-04

Table 3: detailed test results

Run #	SN #	Vin (V)	Vout (V)	Iout (mA)	ION	LET (MeVcm ² /mg)	TILT (°)	Eff LET (MeVcm ² /mg)	Fluence (#/cm ²)	SET #	X SET (cm ² /dev)
43	13.3	1.5	100	Xe	58.72	45	83.04	1.38E+05	102	7.39E-04	
44	13.3	1.5	100	Xe	58.72	0	58.72	8.29E+04	109	1.31E-03	
45	13.3	1.5	500	Xe	58.72	0	58.72	1.86E+05	103	5.54E-04	
46	13.3	1.5	500	Xe	58.72	45	83.04	5.30E+04	114	2.15E-03	
47	13.3	1.5	1000	Xe	58.72	45	83.04	1.83E+05	216	1.18E-03	
48	13.3	1.5	1000	Xe	58.72	0	58.72	1.65E+05	145	8.79E-04	
49	13.3	1.5	1000	Xe	58.72	0	58.72	8.47E+04	95	1.12E-03	
50	13.3	1.5	1000	Xe	58.72	0	58.72	1.00E+06	625	6.25E-04	
51	13.3	1.5	1000	Xe	58.72	0	58.72	2.00E+04	16	8.00E-04	
53	23.3	1.5	1000	Xe	58.72	0	58.72	1.16E+05	97	8.36E-04	
54	23.3	1.5	1000	Xe	58.72	45	83.04	8.55E+04	108	1.26E-03	
55	23.3	1.5	500	Xe	58.72	45	83.04	1.14E+05	99	8.68E-04	
56	23.3	1.5	500	Xe	58.72	0	58.72	2.79E+05	167	5.99E-04	
57	23.3	1.5	100	Xe	58.72	0	58.72	2.21E+05	104	4.71E-04	
58	23.3	1.5	100	Xe	58.72	45	83.04	1.48E+05	108	7.30E-04	
60	23.3	1.5	10	Xe	58.72	45	83.04	1.60E+05	115	7.19E-04	
62	23.3	1.5	10	Xe	58.72	0	58.72	4.86E+05	205	4.22E-04	
63	23.3	1.5	10	Xe	58.72	0	58.72	2.56E+05	108	4.22E-04	
101	13.3	1.5	500	Kr	31.28	0	31.28	8.54E+04	121	1.42E-03	

TPS76701

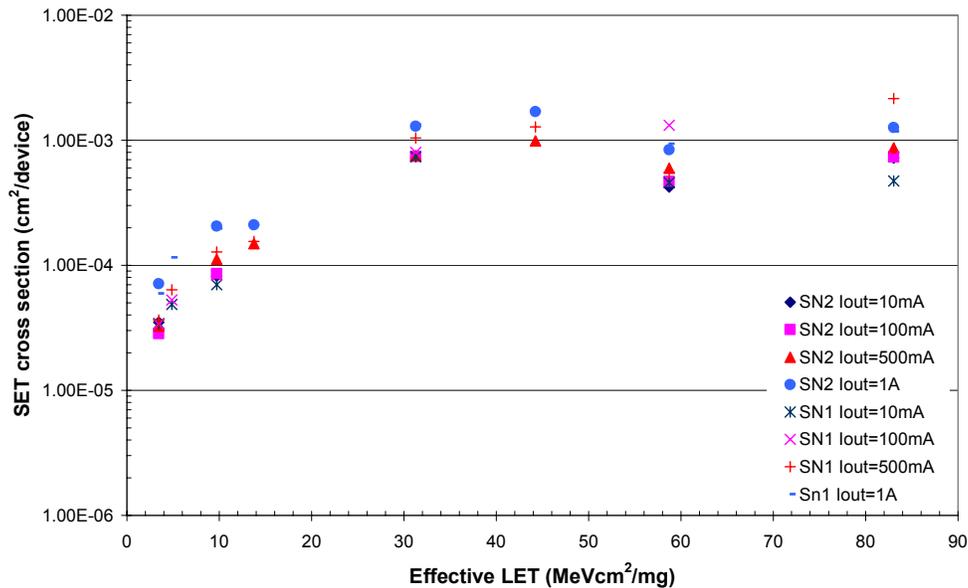


Figure 3: SET cross-section

Up to a load current of 500 mA, SETs are small amplitude negative going transients. Typical SET waveforms are shown in Figure 4.

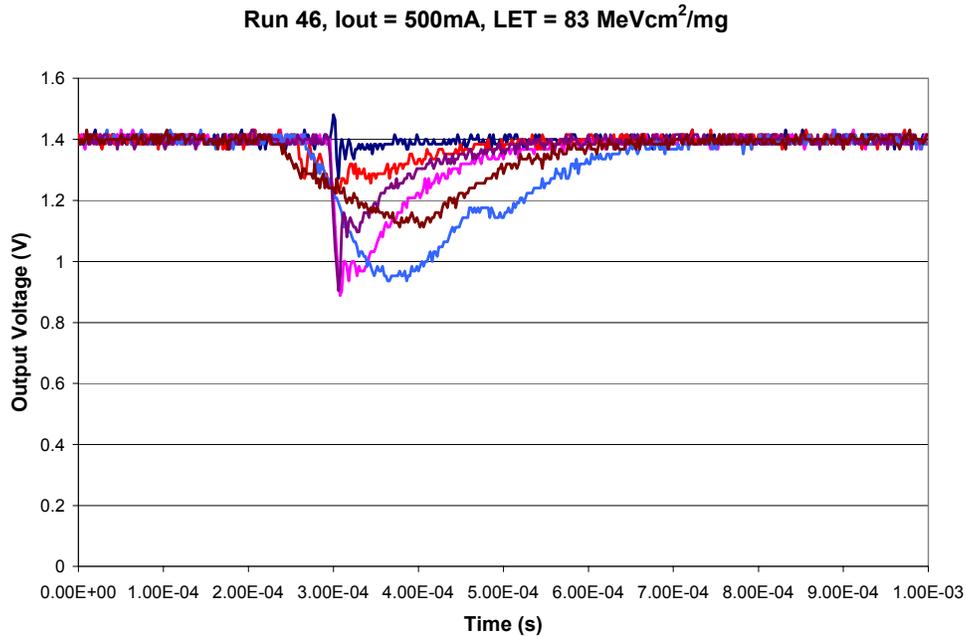


Figure 4: Typical SET waveforms up to load current of 500 mA

Figure 5 shows SET amplitude versus FWHM plot for all transients collected during the same irradiation run. Maximum transient amplitude is 510mV, and maximum transient FWHM is about 180 μ s.

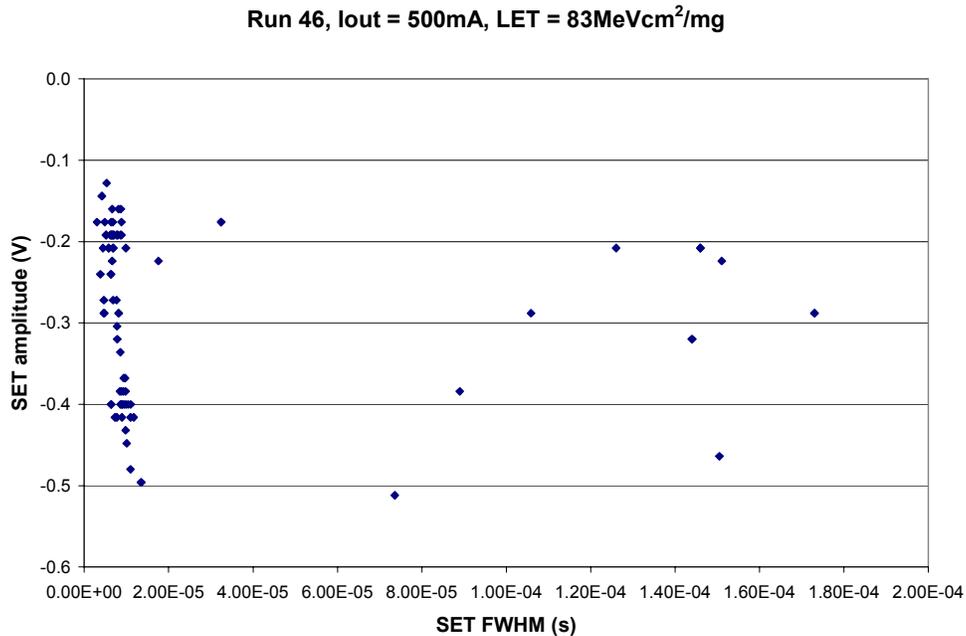


Figure 5: SET amplitude versus FWHM plot for all SETs collected during irradiation run 46

Fig 6 shows typical transients for the largest tested load of 1A. Most transient have a large amplitude. Device output voltage goes down to 0V for the largest transients. Some of these transients have a very long duration. This duration can be longer than 7 ms. It is possible that in some cases ions trigger the device current limit protection circuitry, and then cause these long transients. Figure 7 shows SET amplitude versus FWHM plot for all transients collected during run 47. About 20% of SETs are long duration transients.

Run 47, Iout = 1A, LET = 83 MeVcm²/mg

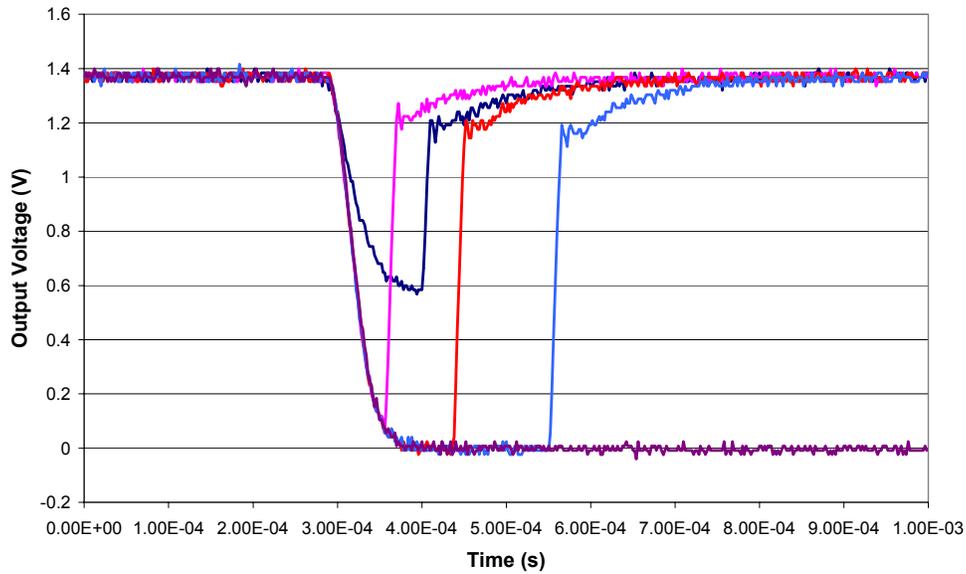


Fig 6: Typical SET waveforms for the load current of 1A.

Run 47, Iout=1A, LET=83 MeVcm²/mg

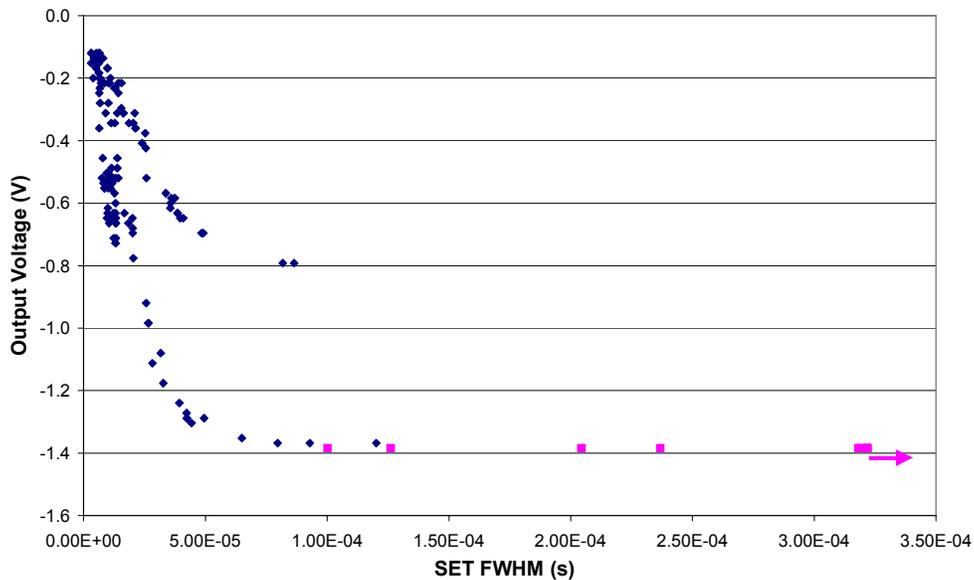


Fig 7: SET amplitude versus FWHM plots for all SETs collected during run 47.